



Natural resource sector FDI, government policy, and economic growth: Quasi-experimental evidence from Liberia



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ABSTRACT

Governments use a variety of policies to increase the impact of foreign investment on economic growth. An increasingly popular policy is to require that foreign companies provide public goods near the communities where their commercial investments are sited. This approach seeks to crowd in additional investments, create clusters of interconnected firms, and set in motion economic agglomeration processes. Post-2006 Liberia represents an ideal empirical setting to test the effectiveness of this approach. We construct a new dataset that measures the precise locations of 557 natural resource concessions granted to investors. We then merge these data with a remotely sensed measure of nighttime light growth at the 1 km × 1 km grid cell level and analyze it using a matched difference-in-differences strategy. We find heterogeneous treatment effects across sectors and investor types: mining (specifically iron-ore) investments projects have positive growth effects, while agriculture and forestry investment projects do not; furthermore, concessions granted to Chinese investors have positive growth effects while those given to U.S. investors do not. These patterns of heterogeneous treatment effects across sectors and investor types are consistent with the theory of change underpinning the government's development corridor strategy.

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1. Introduction

Estimating the economic effects of foreign direct investment (FDI) is a challenge that has vexed scholars and policymakers for decades. The effects of FDI almost certainly vary across country and project characteristics, making generalizations difficult. In addition, even though FDI projects are sited in specific locations, available data are typically aggregated to the country level resulting in imprecise estimates.¹ Faced with these challenges, scholars have turned to sub-nationally geo-referenced investment, outcome, and covariate data and quasi-experimental methods of causal inference (Aragón & Rud, 2013, 2016; Fafchamps, Koelle, & Shilpi, 2016; Knutsen, Kotsadam, Olsen, & Wig, 2017; Zhu, 2017). We make three contributions to this emerging body of work.

First, we evaluate the impact of FDI on local economic growth outcomes in post-2006 Liberia, which pursued a unique policy approach: in contrast to previous approaches—where host governments provided public goods to attract foreign investors—the Ellen Johnson-Sirleaf administration has required that foreign companies provide public goods. It has granted concessions that allow foreign investors to extract iron ore, gold, palm oil, timber, rubber, and other natural resources. However, these concession agreements also stipulate that investors must build and maintain public infrastructure—including roads, bridges, ports, railways, and power plants—near the communities where their commercial activities are sited. This strategy seeks to create new ‘development corridors’ by using privately provided public goods to set in motion economic agglomeration processes (Speakman & Koivisto, 2013).

Second, we identify the specific conditions under which this approach is most effective. We do this by assembling a dataset of all known natural resource concessions that the Liberian government granted to investors between 2004 and 2015, and then geo-referencing this dataset by constructing polygons that correspond to the specific tracts of land granted to concessionaires. We also categorize each concession by sector and investor type.

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¹ See Section 2.1 of the Online Appendix for a review of this literature.

Third, in order to address the non-random assignment of the treatment (i.e. the possibility that locations with FDI may be different from locations without FDI in a way that threatens causal inference), we use a propensity score matching procedure to first prune our sample such that it only includes ‘treated’ and ‘untreated’ locations that are extremely similar across a large number of observed covariates and equally likely to receive treatment. This procedure minimizes the risk that ‘treated’ locations have features that predispose them to higher levels of economic growth independently of FDI. We then use a difference-in-difference strategy to compare changes in local economic growth in otherwise similar subnational localities with and without investment projects. We use a remotely sense measure of nighttime light growth as a proxy for local economic growth (Henderson, Storeygard, & Weil, 2012; Weidmann & Schutte, 2017).

We recognize that investments in the natural resource sector may have negative, second-order effects, such as increased corruption and environmental degradation (Aragón & Rud, 2013; Knutsen et al., 2017). With respect to initial effect of FDI on economic outcomes, however, our results suggest that extractive sector FDI has improved local economic growth in Liberia. We also find a pattern of heterogeneous treatment effects that is consistent with the theory of change underpinning the government’s development corridor strategy. Concessions that were subject to more demanding public good provision requirements (mining investment projects in general and iron ore investment projects in particular) produced higher levels of economic growth than those that faced less demanding public good provision requirements (agricultural and forestry investment projects). Likewise, those investors that were particularly well-positioned to meet the public good requirements of the host governments (Chinese concessionaires) achieved larger economic growth impacts than investors that were less well-positioned to meet such requirements (U.S. concessionaires).²

2. Liberia’s FDI strategy

Governments have historically pursued three different strategies to increase the impact of foreign investment on domestic economic growth. Some governments have put their trust in the market mechanism and liberalized FDI inflows (Williamson, 2000, p. 252). These governments have refrained from regulating or directing foreign investment in the hopes that the market would instead identify the most optimal use of resources. A second strategy has involved the imposition of geographic restrictions by allowing foreign investors to operate only in specifically designated export processing zones. In these cases, governments hoped that the presence of foreign firms would enhance the productivity of domestic labor—for example, by training and educating a locally sourced labor force (Fosfuri, Motta, & Rønde, 2001; Gorg & Strobl, 2005). A third strategy has involved the imposition of operational requirements that foreign firms enter into joint ventures with domestic companies and share their technologies with indigenous firms. In these cases, government policy has focused on facilitating technology transfer (Wang & Blomström, 1992).

However, these strategies are most relevant to countries with existing infrastructure and an entrepreneurial base ready to benefit from knowledge and technology transfers. Liberia lacks these preconditions and has pursued a different strategy. The novelty of its approach is that, rather than supplying public goods for use by private investors, the government has required that incoming

investors provide public goods in or near the communities where their investments are physically sited. This strategy is premised on the idea that the concentration and co-location of private and public investments in specific geographic areas will crowd in additional investments, create clusters of interconnected firms, nurture the development of value chains, and set in motion economic agglomeration processes (Speakman & Koivisto, 2013).³

More specifically, the Johnson-Sirleaf administration has pursued a strategy of “develop[ing] spatial corridors off the back of concession-sponsored infrastructure” (AFDB, 2013, p. 34).⁴ In 2010, it articulated this strategy:

“[our] development corridor strategy will allow growth to accelerate by ‘crowding in’ investment, creating synergies among diverse activities along growth axes where users can share road-, rail-, port-, power-, telecommunications- and water infrastructure. . . . In the past, wasteful practices included mines created as autonomous island investments with their own infrastructure. Potential other users were closed out. . . . [Our] development corridor approach identifies potential other users of infrastructure from the start, and factors them into the design of the infrastructure. Planning shared infrastructure and communicating effectively with investors and communities can accelerate the process, reduce wasteful duplication of effort and improve both investor and community benefits.” (Government of Liberia, 2010, p. vii).

The Government of Liberia’s strategy assigns a higher level of priority to physical infrastructure investments than social sector investments such as schools and hospitals. There are good reasons to believe that the former will have larger, near-term impacts on economic growth than the latter. Existing empirical evidence indicates that investments in economic infrastructure (e.g. roads, railways, bridges, and electricity grids) produce more immediate and easily detectable growth effects (Clemens, Radelet, Bhavnani, & Bazzi, 2011), whereas the economic growth effects of human capital investment can take years, if not decades, to materialize (Mayer, 2001).

There is also descriptive evidence that suggests the government’s strategy of requiring concessionaires to invest in local public good provision may have increased the stock of physical infrastructure. While time-series data for road or rail density are not available, a recent IMF report indicates that about 1000 additional kilometers of roads were paved between 2006 and 2016 (IMF, 2016, p. 35). Liberia’s performance on UNCTAD’s Liner shipping connectivity index, which measures how well countries are connected to global shipping networks, also increased by 60% over the same period. Additionally, data from the World Bank suggest that the percentage of Liberians with access to electricity increased from 0.01% in 2003 to 9.14% in 2014. Yet it remains unclear if these changes have actually resulted in higher local economic growth. Our study seeks to address this question.

³ Alternatively, the government could have taxed foreign investors and used the proceeds to fund infrastructure itself. However, this is not the case in Liberia, for two reasons: First, fiscal revenues from foreign investors are low because the government agreed to generous tax breaks in exchange for concessionaires building public infrastructure (Qaiyim & Siakor, 2014, p. 11). Liberia’s Ministry of Planning and Economic Affairs estimated that the country’s six major iron ore concessions would together generate only \$129 million of government revenue (Government of Liberia, 2010, p. vii). Second, the government revenues that are generated via taxes on foreign investment are not used for specific infrastructure projects. Liberia’s Revenue Authority emphasizes this point, noting that “revenues from the extractive sectors are not earmarked for specific spending or regions in Liberia.” See <https://eiti.org/liberia#revenue-collection>, accessed October 6 2017.

⁴ Also, see Section 2.2 in the Online Appendix.

² We hypothesize that Chinese firms are better-positioned than U.S. companies to implement commercial investments and supply public goods in a timely manner. This might explain why Chinese-financed projects produce near-term economic growth impacts. See p. 14 for additional details.

3. Theory

We rely on Hirschman (1977) to identify two plausible channels through which natural resource sector investment and concessionaire-provided public goods might together result in economic growth: *backward linkages* and *consumption linkages*. Backward linkages to the local economy occur when the production of a given commodity requires the supply of goods and services as inputs. Walker and Minnitt (2006) and Bloch and Owusu (2012) note that the mining industry requires a large and diverse set of inputs, including raw materials (e.g. chemicals, steel), equipment (e.g. drills, generators, pumps), parts (e.g. cables, pipes), and engineering, construction, survey, legal, finance, insurance, laboratory, catering, vehicle maintenance, and transportation services. These linkages should be even stronger in geographical areas that enjoy higher levels of public good provision, as the availability of local infrastructure and public services should reduce the costs of doing business. Firms should also be able to more easily reach markets and integrate themselves into value chains in such areas (Speakman & Koivisto, 2013).

Consumption linkages refer to local spending that occurs as a result of increased incomes (from either wages or profits) related to commodity production. Employees spend their income, in part, on non-mining related goods and services (e.g. food, clothing, taxi services), and this in turn creates more opportunities for non-mining related enterprises. Tolonen (2014) provides evidence that the establishment of a new mine increases income-earning opportunities within the service sector by 41%. In Ghana, Fafchamps et al. (2016) find that locations close to gold mines had proportionally higher employment in industry and services, which suggests a shift from the informal to the formal sector. Chuhan-Pole, Dabalén, Kotsadam, Sanoh, and Tolonen (2015) show that both men and women benefit monetarily from gold mines, but men are more likely to obtain direct employment as miners and women are more likely to gain from indirect employment opportunities in services. Relatedly, Kotsadam and Tolonen (2016) find that increases in mining activity result in sectoral shifts in employment out of agriculture: men move into skilled manual labor, while women find more employment in the service sector. These economic multiplier effects should be even larger in settings where public goods are provided.⁵ We therefore test the following hypothesis:

Hypothesis 1. Natural resource concessions will, on average, result in a higher level of economic growth in surrounding areas.

When examining the effects of natural resource sector investments with concessionaire-provided public goods, one would ideally distinguish between the specific private investment sites and the public goods provided in communities near concession areas (e.g. investments in general purpose roads vs. mine access roads). But for the vast majority of concessions in our dataset, such information is not available in publicly available contracts.

We do, however, have strong *a priori* reasons to believe that public good requirements included in concession contracts vary systematically by sector. The Liberian government's development corridor strategy rests on the assumption that only mining investors are able to plausibly finance large-scale transportation infrastructure themselves: "[m]ining is generally the only activity that can self-fund major transport infrastructure and thus anchor new development corridors" (Ministry of Planning and Affairs, 2011).

Therefore, we expect that mining concessions will result in stronger backward linkages than agriculture or forestry concessions.

We also expect to see a larger multiplier effect from the consumption linkages developed through mining concessions. The rationale for this expectation is again outlined in the Liberian government's development corridor strategy: "mining itself is capital intensive and can generate comparatively few jobs. ...The infrastructure it finances, however, can generate/sustain tens of thousands of jobs, both in mining-linked investments and in complementary value chains that are more labor intensive" (Government of Liberia, 2010, p. 54). For these reasons, we expect to observe a pattern of heterogeneous treatment effects across mining versus agriculture and forestry concessions.⁶

Hypothesis 2. Mining concessions will, on average, have larger impacts on economic growth than agricultural or forestry concessions.

We can also differentiate between different types of mining activities. Iron ore differs from mining gold, diamonds, bauxite, and base metals in that it offers the possibility of large profits over long periods of time, which makes it easier for companies to justify major, up-front investments in infrastructure. Our dataset reveals that the average duration of contracts granted to iron ore concessionaires is 21 years, in contrast to just 9 years for other mining concessions. The average capital expenditures of iron ore investors are \$1.6 billion, while those of other mining concessionaires equal only \$43.2 million (Government of Liberia, 2010). Iron ore investors therefore have limited exit options and a weaker bargaining position vis-à-vis the host government.

Recognizing these constraints, the Liberian government has imposed particularly heavy public good requirements on incoming iron ore investors (AFDB, 2013). Specifically, the Johnson-Sirleaf administration has prioritized the development of three spatial development corridors near three major iron ore concessions: one near the Western Cluster iron ore deposit, a second near the Putu iron ore deposit, and a third near the Mount Ganga, Mount Tokadeh and Mount Yuelliton deposits (see Section 2.2 of the Online Appendix for more details). These "new iron ore concessions are [at] ...the center of a new development strategy based on development corridors. ...The idea is to have concession-sponsored infrastructure (roads, rail, ports, power and water) catalyze [economic] activity in other sectors within viable logistics proximity. Explicit provisions are being made in concession agreements to that end" (AFDB, 2013, p. 33). For these reasons, we expect to observe systematically different local economic agglomeration effects across different types of mining investments:

Hypothesis 3. Iron ore concessions will, on average, have larger impacts on economic growth than other types of mining concessions.

An investor's country of origin could also matter for local economic growth outcomes. First, managerial approaches related to employment might differ in ways that are economically consequential. Some analysts have argued that, in contrast to U.S. companies, Chinese firms have a preference for hiring Chinese workers instead of local labor to support their overseas investments (Dollar, 2016). Such hiring practices, if widespread, could limit the growth-enhancing effects of FDI by undermining the development of consumption linkages. However, it seems unlikely that this mechanism is operating in Liberia. The Ellen-Johnson Sirleaf

⁵ Note that Liberia has attracted very few greenfield investments. Virtually all FDI is located in the natural resource sector, which requires investors to obtain concessions (Werker & Beganovic, 2011). Therefore, it is not possible to compare FDI with and without concessions.

⁶ Note that we cannot compare mining and agriculture concessions to manufacturing FDI. While the literature has found that manufacturing can play an important role in generating production externalities, this type of FDI is largely nonexistent in Liberia (Werker & Beganovic, 2011).

administration has uniformly imposed local labor requirements on foreign investors, irrespective of their countries of origin.⁷ There is also very little empirical evidence that Chinese companies primarily use Chinese labor. Sautman and Hairong (2015) examine a sample of 400 Chinese firms operating in Africa and find that 85% of their employees are local hires. Likewise, Warmerdam and van Dijk (2013, p. 292) and World Bank (2012, p. 22) find that roughly 90% of the workers employed by Chinese companies in Uganda and Ethiopia, respectively, are local hires. Given that U.S. companies in Africa also rely very heavily on local labor (Rounds & Huang, 2017, p. 26), it seems unlikely that different labor sourcing practices would account for heterogeneous treatment effects across U.S. and Chinese concessionaires.

Second, while the Liberian government generally expects concessionaires to adhere to the same set of rules and norms independently of the country of origin, there could be differences in the enforcement of these standards that correlate with investors' countries of origin. With respect to corruption, for example, Chinese companies might be less constrained by international rules and thus more likely to use bribes to overcome operational impediments in Africa. However, in Liberia, it seems unlikely that U.S. and Chinese investors are differentially constrained by international rules. The European Accounting and Transparency Directive and Section 1504 of the Dodd Frank Act require natural resource companies listed on U.S. and European stock exchanges to disclose payments made to African governments in exchange for concessions, but only two out of 36 U.S. concessionaires operating in Liberia are listed on U.S. or European stock exchanges. Nor is there much evidence to support the claim that Chinese and U.S. firms comply at different rates with domestic rules and norms in host countries (Irwin & Gallagher, 2013; Rounds & Huang, 2017; Sautman & Hairong, 2012).

A third possibility is that Chinese firms are better positioned than U.S. companies to implement commercial investments and supply public goods in a timely manner. The U.S. embassy reported in 2009 that, during the vetting of proposals from prospective iron ore concessionaires, the Liberian authorities favored Chinese investors because of their willingness and ability to implement private and public investment activities on an expedited schedule.⁸ Around the same time, the former President of Senegal, Abdoulaye Wade, published an op-ed in the *Financial Times*, noting that "China has helped African nations build infrastructure projects in record time" and "I have found that a contract that would take five years to discuss, negotiate and sign with the World Bank takes three months when we have dealt with Chinese authorities."⁹ Dreher, Fuchs, Parks, Strange, and Tierney (2017) provide causal evidence that the firms responsible for implementing Chinese-financed infrastructure projects produce large and near-term economic growth impacts, whereas U.S.-financed infrastructure projects deliver economic growth benefits that accrue over longer periods of time. This reason for expecting differential growth impacts across investor nationalities would therefore seem to be more plausible than the alternative explanations summarized above.

Hypothesis 4. Chinese concessions will, on average, register more easily detectable growth impacts than U.S. concessions.

4. A quasi-experimental approach

4.1. Matching approach

Estimating the effect of FDI on economic growth is challenging because models only provide valid causal estimates if they are unaffected by endogeneity. A major threat to causal inference is the possibility that FDI does not cause growth, but investors are instead attracted to geographic locations with high growth potential. A positive correlation between local economic growth and FDI might only indicate that the very same locations that received FDI would have also experienced the same level of growth in the absence of FDI.

We address the possibility that locations with FDI may be different from locations without FDI in a way that threatens causal inference with a matching approach. We prune our sample to only include 'treated' and 'untreated' locations that are extremely similar across a large number of observed covariates. This procedure is designed to expunge any potential effects of self-selection bias—that is, the possibility that 'treated' locations have features that predispose them to higher levels of economic growth independently of FDI. Our goal, then, is to identify pairs of treated and untreated locations that are equally likely to receive treatment.

Given that matching only helps mitigate endogeneity problems if it is possible to measure relevant factors that influence treatment assignment, we carefully reviewed the existing literature on the subnational project siting decisions of foreign investors.¹⁰ A wide range of factors influence where investors site their projects within countries, including climatic conditions, market size and access, human capital, transportation infrastructure, and local governance quality. We attempt to account for as many of these factors as possible by drawing upon diverse sources of data from satellite imagery, weather stations, household surveys, and administrative records.¹¹

Our spatial units of observation are 1 km × 1 km grid cells that fall within buffers around each Demographic and Health Survey (DHS) Enumeration Area (EA). We rely on the 2007 wave of DHS, which contains 298 spatially referenced EAs. DHS EAs are subjected to displacement procedures to protect respondent anonymity. In most cases, urban EAs are displaced by up to 2 km, while rural ones are displaced by up to 5 km. We create buffers around EAs to account for geographical displacement. After creating buffers with a radius of either 2 or 5 km, depending on the type of EA, we create 1 km × 1 km grid cells within the area encompassed by each buffer. We begin the matching process with approximately 13,000 observations at the grid-cell level.

In order to identify locations that are as similar as possible across our covariate data, we first employ a logit model that estimates the probability that a given grid cell is proximate to a FDI location (Ho, Imai, King, & Stuart, 2007; Imai, King, & Stuart, 2008). This logit model is then used to derive the propensity that the units will 'receive the treatment' of exposure to the concession. The propensity score is, in turn, used in a nearest-neighbor

⁷ The Government included almost identical local employment provisions in its contracts with Mittal Steel Liberia (a major Western concessionaire) and China Union (a major non-Western concessionaire). China Union's 2009 concession contract states that "[t]he Concessionaire may not hire individuals who are not citizens of Liberia for unskilled labor positions." It also specifies that "[t]he Concessionaire must employ and give preference to the employment of qualified citizens of Liberia for financial, accounting, technical, administrative, supervisory, managerial, and executive positions and other skilled positions."

⁸ "Liberia: Chinese Firm Wins Bid to Develop Bong Iron Ore Mine." *U.S. Embassy Cable*, January 21, 2009.

⁹ "Time for the West to practice what it preaches," *Financial Times*, 23 January 2008.

¹⁰ See Section 4.1 in the [Online Appendix](#).

¹¹ Importantly, we match on pretreatment nighttime light levels and trends (Cook, Shadish, & Wong, 2008). In addition, we present average nighttime light values over the course of the pretreatment period (1992–2005) across our treated and control units. Our findings indicate that, after matching, pretreatment levels of nighttime light were roughly parallel, which suggests that in the absence of treatment the nighttime light differences across our treatment and control cases (matched locational pairs) would have been constant over time. See Sections 4.1 through 4.6 of the [Online Appendix](#).

matching routine (caliper = 0.25)¹² to create a matched sub-sample of treatment and control units, where the ‘treated’ grid cells are those near concession areas and ‘control’ grid cells are those far away from concession areas.

After estimating the propensity scores, we first drop units that lack common support, and then match grid cells without replacement using the nearest-neighbor approach. Matching without replacement forces the algorithm to sample from a wider geographic area, which minimizes the probability that our matched pairs will cluster in one area and thus accounts for possible biases resulting from spatial selection effects (e.g. geographic treatment spillovers from one location to a neighboring location).

If this matching procedure was successful, the treated and untreated samples should be nearly indistinguishable, apart from the fact that the former group was proximate to FDI and the latter group was not. Our matching procedure accomplishes this goal: the observable characteristics of our treated and untreated locations after matching are almost identical. After matching, covariate balance improves by approximately 90%.¹³ This suggests that our subsequent statistical analysis compares only location pairs that are extremely similar, which significantly reduces the risk of endogeneity bias.¹⁴

4.2. Empirical analysis

We estimate the growth impacts of natural resource sector FDI using a matched difference-in-differences (DID) strategy. Our estimation strategy first identifies matched pairs of cells, and then calculates the difference in the average change in nighttime light in the treatment locations before and after treatment minus the difference in the average change in nighttime light in the control locations before and after treatment. An attractive feature of this approach is the ability to control for time-invariant, unobservable characteristics that might also affect economic growth.

With our preprocessed data, we estimate a linear model with the set of matched control and treatment units for each hypothesis following:

$$y = \beta_0 + \beta_1 \times T + \sum_{k=1} (B_k \times x_k) + \beta_k \times P_y + D_\tau + \epsilon \quad (1)$$

where B_k and x_k are the regression coefficients and covariate information for each indexed covariate (k), β_1 is the regression coefficient for the treatment effect, T , and y represents the outcome variable over our study interval. P_y is the pre-treatment trend for the outcome variable. D_τ represents fixed effects for regions. We cluster errors by DHS enumeration areas to mitigate concerns of within-cluster spatial autocorrelation and the potential deflation

¹² The caliper determines the degree of similarity two locations must demonstrate to be considered as a matched pair. A 0.25 caliper is a common “best practice” in studies using propensity score matching for causal inference (Lunt, 2013; Rosenbaum & Rubin, 2012). As a robustness test, we re-estimate all models using a caliper of 0.1. This stricter criterion for identifying matched pairs results in a reduced sample size. However, our results do not change substantively; see Section 5.3 of the Online Appendix.

¹³ The matching procedure leveraged here optimizes by selecting the best match for each individual treated cell, thus aiming to match along all elements of the distribution. We calculate this overall summary of the balance improvement by observing the change in mean differences after balancing (Ho et al., 2007). Each unit of observation is matched according to its propensity score on a unit-by-unit basis to the best-matched control; we seek to minimize the difference in propensity score between matched pairs. See Sections 4.2 and 4.3 in the Online Appendix.

¹⁴ Matching approaches are only as useful as the set of observed covariates used to achieve balance between treatment and control units. We cannot completely rule out the possibility that some unobserved confound biases our findings. Therefore, we make similar assumptions as instrumental variable approaches, which need to assume that there are no unobserved variables linking the instrument to the outcome except through the path of the instrumented variable.

of standard errors attributable to arbitrary grid cell sizes (Cameron, Gelbach, & Miller, 2012).

We measure our outcome of interest—local economic growth—using satellite data on nighttime light emissions. We use this measure for three reasons. First, Fig. 1 demonstrates that in Liberia there is a very strong relationship between GDP and nighttime light at the national level.¹⁵ The bivariate correlation between these annual GDP and nighttime observations is 0.91. Second, previous research demonstrates that nighttime light is a useful measure of local economic activity (Henderson et al., 2012; Jean et al., 2016). Third, we lack an alternative measure of local economic growth. DHS surveys measure asset wealth at the household level, but do not provide time-series data as the various survey waves sample households in different enumeration areas. However, Weidmann and Schutte (2017) demonstrate that levels of nighttime light correlate strongly (0.73) with survey-based measures of asset wealth at the local level. Similarly, Khomba and Trew (2017) demonstrate that changes in nighttime light also correlate strongly (0.53) with changes in household consumption.

While nighttime light is the best available proxy measure for subnational economic growth, it is not without limitations. For reasons of space, we discuss these limitations—and how we address them—in the Online Appendix.¹⁶ To construct our outcome variable, we calculate the change in nighttime light levels over the full treatment period (2006–2012) for each 1 km × 1 km grid cell.

Our causal variable of interest is foreign direct investment in the natural resource sector. We assembled a dataset of all known natural resource concessions granted to concessionaires in Liberia from 2004 to 2015.¹⁷ Fig. 2 demonstrates that these concessions are evenly distributed across Liberia and do not cluster in any part of the country. Each of the 557 concessions in this dataset is classified according to the sector of the concession and the nationality of the concessionaire or its parent company. A polygon-based geocoding methodology was also used to identify the specific tracts of land granted to concessionaires, which allows us to calculate at a high-level of spatial resolution whether a particular location has been ‘treated’ with FDI activity.

We sub-divide our concessions dataset by sector and investor nationality to test each of our hypotheses. A 1 km × 1 km grid cell is considered ‘treated’ if it falls within 25 km of a given concession type. For example, when we evaluate the nighttime light impacts of Chinese concessions, we classify all cells that fall within 25 km of a Chinese concession as ‘treated.’¹⁸

The choice of 25 km as the distance threshold requires justification, as other studies have used thresholds ranging from 20 km (Kotsadam & Tolonen, 2016) to 100 km (Aragón & Rud, 2013). At a theoretical level, we ought to pick a threshold appropriate for the country’s size; more specifically, the expected range across which economic effects of FDI projects might diffuse should guide our choice of a distance cutoff for treatment status. We therefore use a plausible range of commuting distances for workers as a proxy. While no such information is available for Liberia, data from

¹⁵ We thank Bundervoet, Maiyo, and Sanghi (2015) for providing us with their data to produce this Figure.

¹⁶ See Section 3.2 of the Online Appendix.

¹⁷ For more details on this dataset, see Section 3.1 of the Online Appendix.

¹⁸ When calculating our results, there is a risk that cells in the control group are contaminated by other types of concessions. When analyzing the effect of Chinese concessions, our control observations are defined as locations not exposed to Chinese concessions. However, this definition of control units may include locations exposed to U.S. concessions, as long as they are not close to Chinese concessions. This overlap, however, is not problematic as it introduces a conservative bias: if U.S. concessions increase local growth, control locations should light up more so than if they were not exposed to any concession at all. This makes finding statistically significant differences across treatment and control units more difficult.

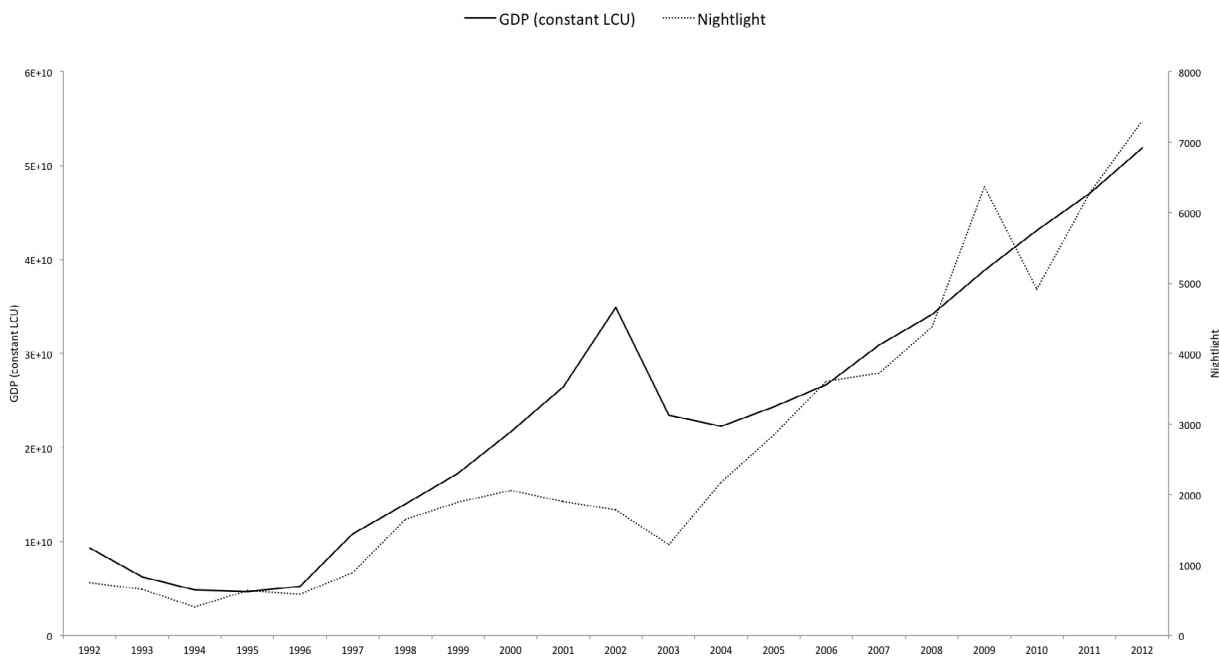


Fig. 1. GDP and Nighttime Light in Liberia, 1992–2012.

neighboring Ivory Coast suggest that 0 km to 25 km is a reasonable estimate (Kung, Greco, Sobolevsky, & Ratti, 2014, p. 6).

We also face empirical constraints that limit the use of certain thresholds. More specifically, the larger the radius used to define which locations are treated, the lower the number of locations that we can consider as (matched) counterfactual cases. Without a reasonable number of untreated locations available for matching, we cannot conduct the statistical analysis. In a country of Liberia's size, we cannot calculate estimates for most models if we use a radius of 30 km or higher. Similarly, the smaller the radius used to define which locations are treated, the lower the number of treated observations. In this case, a large number of control locations are available for matching, but the small number of treated locations can leave us with an insufficient number of matched pairs for statistical analysis. We therefore face both an upper and lower limit with respect to possible thresholds. In sum, 25 km represents a distance at which we can estimate effects across *all* our hypotheses.¹⁹

We also include a range of control variables to account for residual variance in our outcome measure (after matching) that is not related to treatment. We control for temperature, precipitation, slope, elevation, the urban or rural nature of the location, population density, distance to roads, travel time to major population centers, proximity to development projects, proximity to natural resource deposits, the politically privileged or disadvantaged nature of a location, pretreatment nighttime light levels and trends, and region fixed effects. We also account for population characteristics (household education and literacy, household wealth, household size) and head of household characteristics (age, gender, marital status, religion, employment status).

¹⁹ As a robustness test, we estimate all models for which we have sufficient data across a range of different threshold distances. These results, reported in Section 5.4 of the Online Appendix, are largely consistent with the results reported here. There are some differences, though, which are to be expected considering the number of estimations performed. Following the frequentist interpretation of confidence intervals, we expect 95 of 100 analyses to contain the actual unknown value of the coefficient. Of the 115 models we estimate, only 6 models (equivalent to 5% of all models) are statistically significant and opposite sign from the estimates reported in the manuscript.

4.3. Findings

We first estimate an overall treatment effect for all concessions over the 2006–2012 period, irrespective of sector or investor type.²⁰ Fig. 3 shows that the overall treatment effect estimate is statistically insignificant.

However, to test the reliability of these results based on comparisons of treated and never-treated localities over the full treatment period, we compare early-treated and late-treated localities to never-treated localities to determine whether treatment impacts are larger in magnitude or more easily detectable in areas where concessions have been active for longer periods of time. The economic agglomeration processes described in the theory section of this paper take place over relatively long spans of time, so one would expect concessions with longer periods of implementation to register larger impacts on nighttime light growth.

Fig. 3 summarizes the results from these early treatment and late treatment tests. For the early treatment test, we include only those concessions activated between 2006 and 2008 and measure nighttime light growth over 2005–2009 period.²¹ The purpose of this test is to examine whether concessions have a measurable impact on nighttime light growth when early grid cells have been partly treated and no late grid cells have been treated. For the late treatment test, we include all concessions activated between 2006 and 2012 but restrict the period of outcome measurement to 2009–2013. Here we examine whether nighttime light growth impacts are larger or more easily detectable when all early grid cells have been treated *and* late grid cells have been partially treated. The early treatment test shows no statistically significant effect of concessions on nighttime light growth, but the late treatment test does. This empirical pattern is consistent with our theoretical expectations: the economic development benefits of natural concessions

²⁰ Tables with the numerical results of the estimations for all Figures are available in Section 1.1 of the Online Appendix.

²¹ We use 2005, rather than 2006, as the baseline year of measurement to ensure that it is not contaminated by treatment effects. We use 2009, rather than 2008, as the endline year of measurement to allow concessions granted near the end of the early treatment period to register detectable effects.

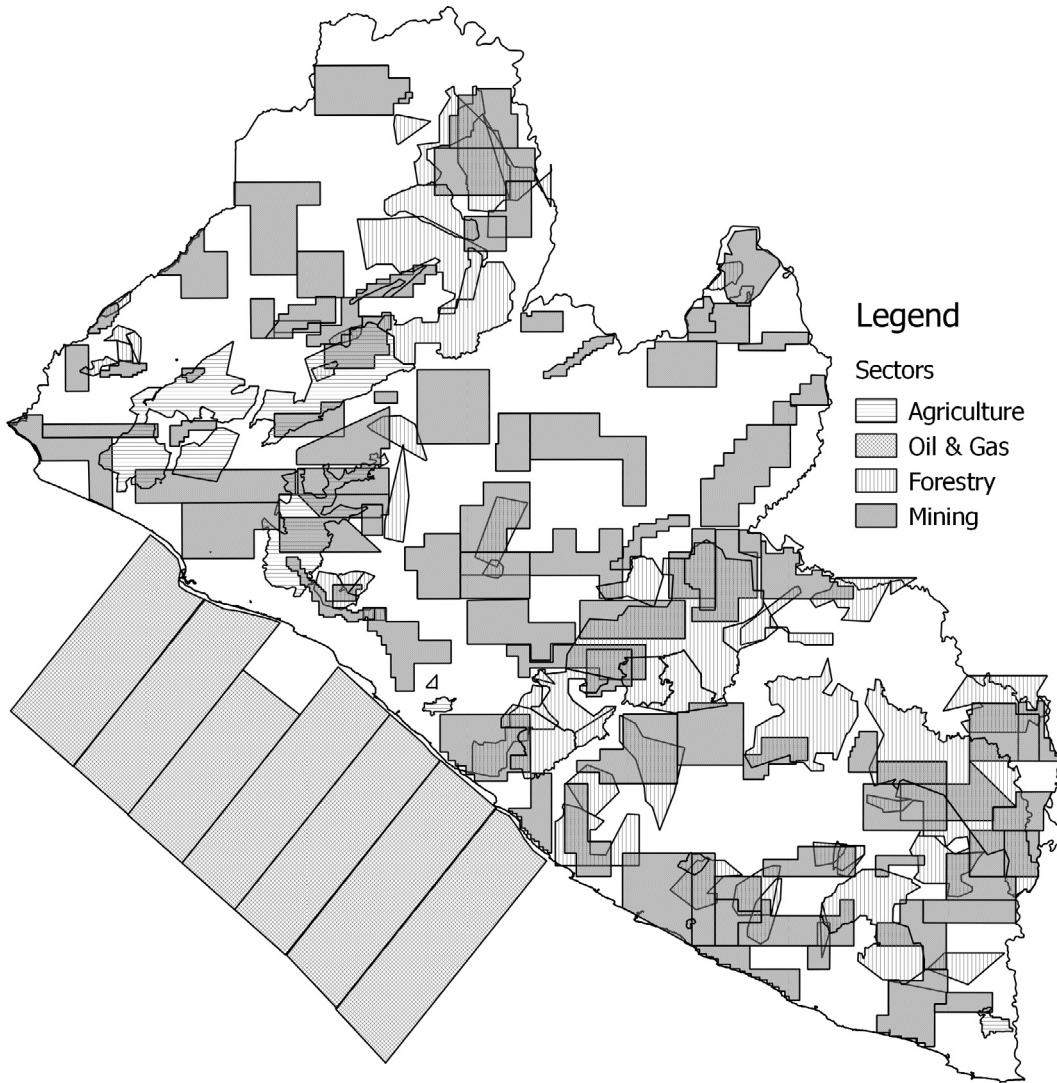


Fig. 2. Map of all concession licenses in Liberia, 2006–2012. In addition to the precise location of concessions, the map differentiates concession by sector.

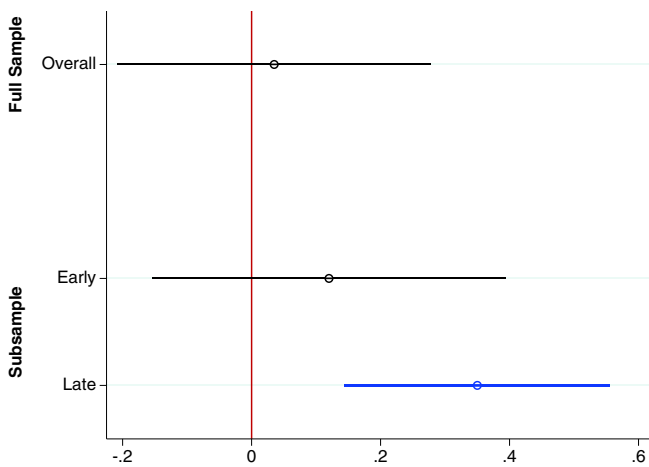


Fig. 3. Effect of all concessions on local economic growth. All Figures show 95% confidence intervals.

However, it is possible that these results mask important sectoral heterogeneity in treatment effects. We first test Hypothesis 2 by separately estimating matched DID models for mining, agricultural, and forestry concessions. Our results are summarized in Fig. 4. Consistent with our expectations, mining concessions have a positive and statistically significant impact on nighttime light growth, whereas agricultural and forestry concessions do not. We can also see in Fig. 4 that the late mining treatment registers a larger positive and statistically significant effect in a matched DID model specification than the early mining treatment.²² This empirical pattern suggests that investments subjected to more demanding public good requirements deliver significant economic growth benefits, but with a time lag. It also suggests that *direct* employment effects are probably not the primary mechanism through which concessions spur economic agglomeration process, as the agriculture and forestry sectors are considerably more labor-intensive than the mining sector (World Bank, 2010, p. 14).

We further disaggregate mining concessions by distinguishing iron ore concessions from other mining operations, such as gold, diamonds, bauxite, and base metals. Fig. 5 provides evidence that

are not immediate; they accrue over a period of time as backward linkages and consumption linkages form and grow.

²² We are unable to estimate early and late treatment effect for agricultural concessions due to insufficient counterfactual observations after matching.

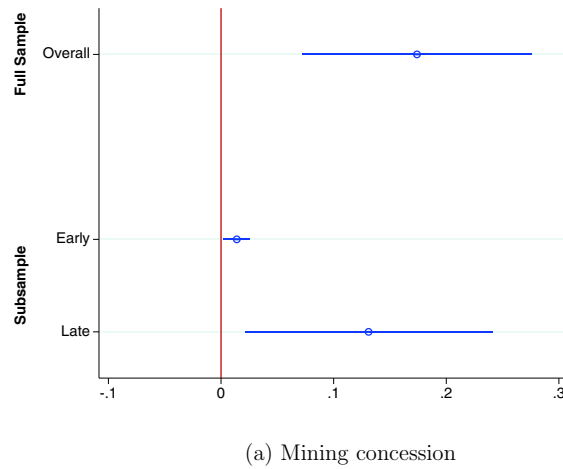
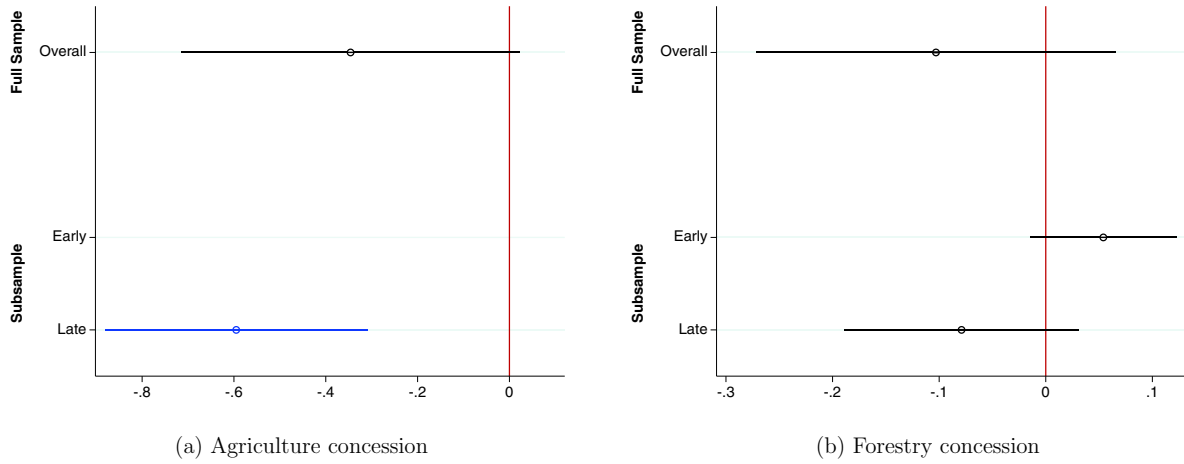


Fig. 4. Effect of mining, agricultural, and forestry concessions on local economic growth.

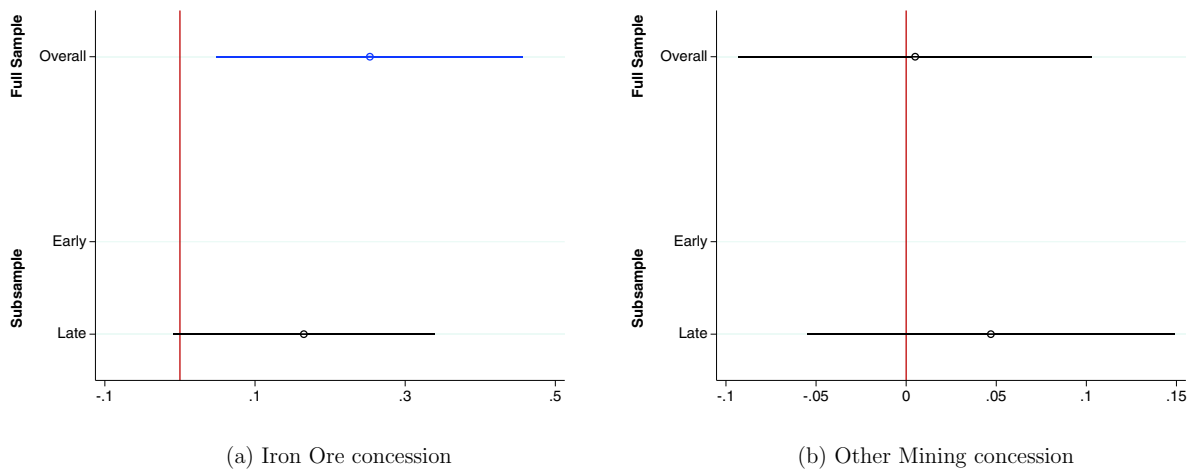


Fig. 5. Effect of iron ore mining concessions and other mining concessions on local economic growth.

supports Hypothesis 3: concessions that subject to particularly demanding public good provision requirements (iron ore investments) produced higher levels of economic growth than those that faced less demanding public good provision requirements.

We also disaggregate treatment effects by investor type. Hypothesis 4 proposed that Chinese companies should have

larger—or more easily detectable—effects on local economic growth than U.S. investors. Fig. 6 shows that U.S. concessions do not have any discernible effect on local economic growth, while Chinese concessions register a positive treatment effect.

However, since Chinese firms are more active in mining sectors than agriculture, it is possible that we have erroneously assigned

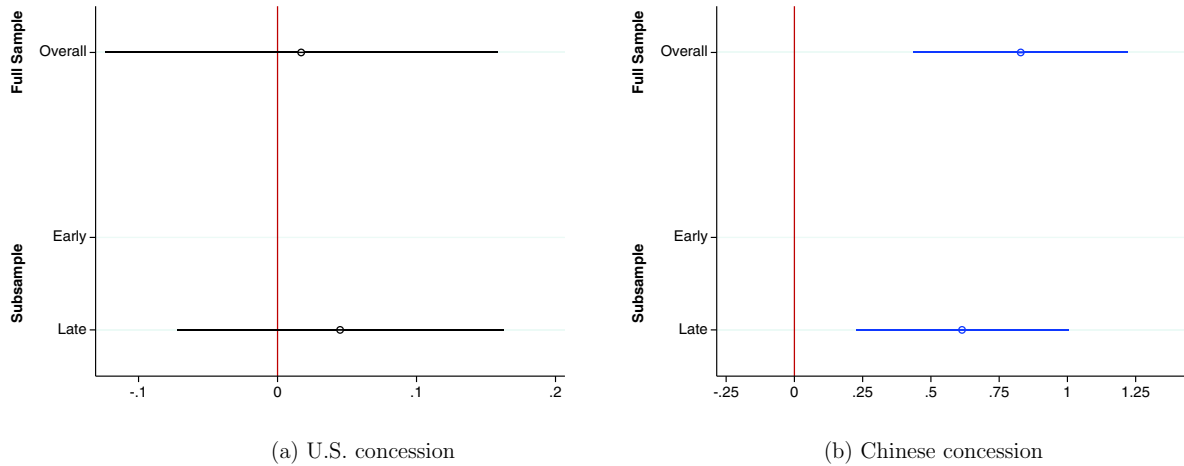


Fig. 6. Effect of U.S. and Chinese concessions on local economic growth.

causal power to investor type differences when in fact we are detecting a sectoral “pass through” effect. Therefore, to account for the possibility that we have conflated investor nationality and sectoral effects, we compare the treatment effects of Chinese and U.S. concessions in the mining sector only. Fig. 7 shows that the differences across investor types still persist, even after controlling for sector. This provides strong support for Hypothesis 4.

4.4. Summary of robustness tests

We also conducted a battery of robustness tests, which are presented in their entirety in the Online Appendix. One potential threat to causal inference is that even after a concession has been granted, a firm might choose not to undertake any investment activities in which case we would not expect any changes in nighttime lights. Systematic information on the implementation status of concessions does not exist; however, we do have information about the exploratory or extractive nature of mining concessions. We expect nighttime light growth to mostly be affected by actual mining extraction activities and not exploratory activities, and Fig. 8 confirms that this is indeed the case. It should also be noted that, in the event investment activities had not begun in a subset of our ‘treated’ locations, the treatment effect sizes that we report would be smaller than they would otherwise be the case if all

‘treated’ locations were in fact treated. Our estimates of investment impacts on nighttime light growth can therefore be interpreted as lower-bound, conservative estimates.

Second, we have assumed thus far that any 1 km × 1 km grid cell will respond in the same manner if exposed to a concession. But this might not be the case: the propensity to ‘light up’ in response to treatment might differ across grid cells. For reasons that we describe in the Online Appendix, a treated location might be more likely to light up if it is physically proximate to road networks. Therefore, we interact a grid cell’s treatment status with that grid cell’s distance from the pre-treatment road network to test the robustness of our findings. The direct, unconditional effects of treatment remain intact after controlling for the propensity to light up.

Third, our main model specification exclude cells exposed to concessions granted prior to 2006 due to endogeneity concerns. Most of these pre-2006 concessions were granted to urban areas, presumably because they were more easily administered by the transitional administration after a long civil war. By excluding these concessions, it is possible that our main model specifications produce results that disproportionately measure treatment effects in rural areas. However, our results remain unchanged if we re-estimate our models by including cells that were exposed to the full set of concessions from 2004–2013.

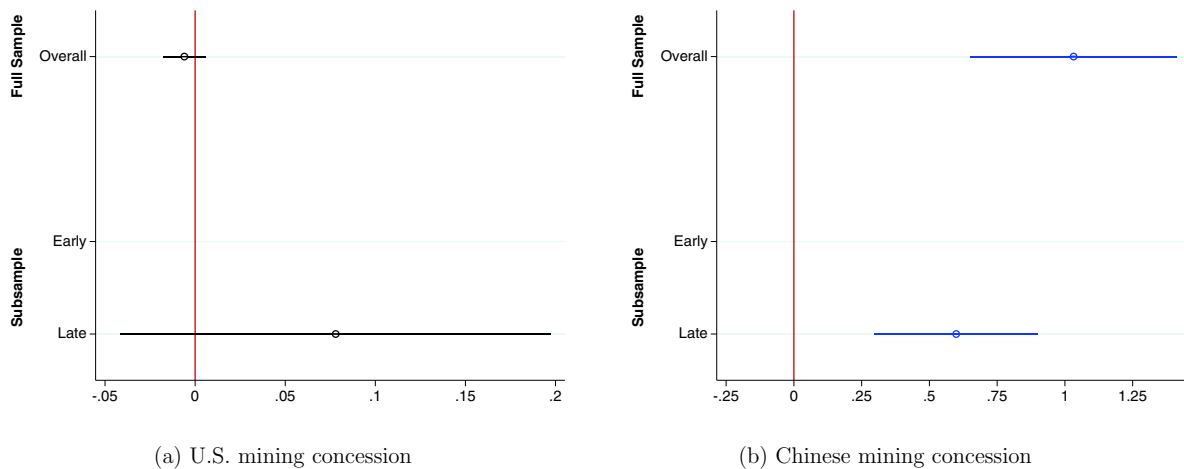


Fig. 7. Effect of U.S. and Chinese concessions on local economic growth.

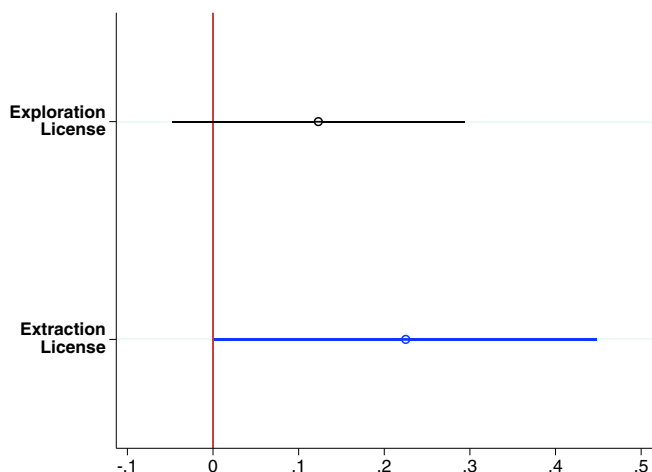


Fig. 8. Effect of exploration versus extraction licenses in the mining sector.

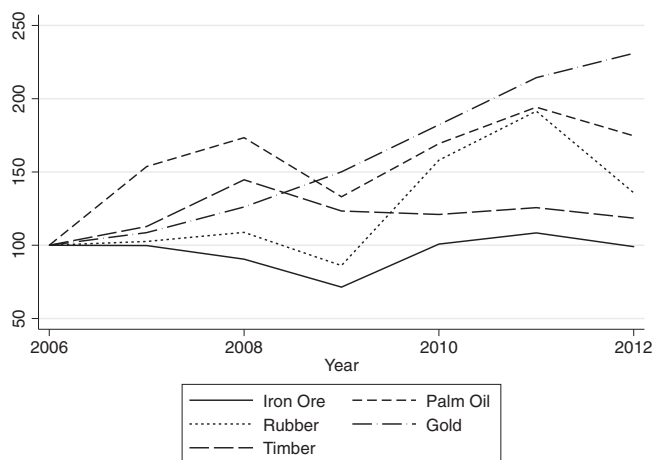


Fig. 9. Price developments of Liberia's main export goods for the period of study. All prices have been converted to an index (Year 2006 = 100) to facilitate comparison.

Finally, in negotiations with potential concessionaires, we assume that the central government has the power to require that their partners provide public goods. However, weakening commodity prices might undermine the bargaining power of the government, as companies should have weaker incentives to invest when prices are low. Yet, Fig. 9 shows that commodity prices have been relatively stable, or even increasing, during our period of study.

5. Case study of Mittal Steel Liberia

The findings from our statistical analysis are consistent with the expected effects of the government's spatial development corridor strategy. However, they do not provide direct evidence of whether FDI generate economic growth in the way that our theory suggests—through the development of backward linkages and consumption linkages. To gain greater leverage on this question, we conducted a case study of an iron ore concession granted to Mittal Steel Liberia (MSL).

We selected this case because it was the first, large-scale iron ore concession that the Johnson-Sirleaf administration granted to a foreign investor and as such it had the longest possible 'gestation period' to set in motion the causal processes that our theory suggests should be at work. Our theoretical argument and economet-

ric evidence suggests that iron ore concessions are a uniquely effective at spurring local economic agglomeration because of the consumption and backward linkages that they help to create. Therefore, if our theoretical argument is valid, we would at minimum expect to see some descriptive evidence that these processes were set in fact motion by the first, large-scale iron ore concession with a reasonably long period of implementation. This type of descriptive evidence does not provide evidence of causation, but it does allow us to evaluate whether our hypothesized causal processes are at least plausible.

The concession agreement between MSL and the Government of Liberia was signed in December 2006, and approved by the Liberian Parliament in May 2007. Under the terms of its 25-year, \$1.5 billion agreement, MSL was granted rights to explore for, extract, and export iron ore from deposits in Mount Gangra, Mount Tokadeh and Mount Yuelliton in Nimba County (Kaul, Heuty, & Norman, 2009), and area of approximately 600 square kilometers.

In exchange for the concession, MSL agreed to spend roughly \$800 million on a 267 km railway from Yekepa (Nimba County) and a port in Buchanan (Grand Bassa County). It also agreed to place special priority on hiring Liberians as opposed to expatriates, and estimated at the time that the 2006 agreement was signed that it expected to directly employ 3,500 people and generate an additional 15,000 to 20,000 jobs via contractors and suppliers (ArcelorMittal Liberia, 2006, p. 40).

To better understand the effects of this concession, we sought to answer three questions: What was the status of the local economy prior to the granting of the concession (pre-treatment conditions)? What specific activities did the investor implement once the concession was granted (the treatment)? Is there any descriptive evidence that suggests these activities may have affected the local economy (post-treatment conditions)?

Information concerning the *pre-treatment conditions* is available from baseline surveys conducted in Nimba, Grand Bassa, and Bong counties. Households in potentially affected areas had average annual incomes of \$79 (URS, 2010). Most residents in these areas were subsistence farmers, or farmers growing rubber, plantains, or cocoa for small amounts of monetary income. Few had access to wage employment in the formal economy. Almost no surveyed households had access to grid electricity or a generator. Enumerators found that "[g]enerally 60% of households use candles for lighting, and 40% use kerosene lamps" (URS, 2010, p. 39).

MSL's activities (the *treatment*), which began in 2007, brought far-reaching changes to the region. The company honored its commitment to provide infrastructure. It rebuilt the 267 km railway from Yekepa to Buchanan; built nearly 100 bridges and various hospitals, schools, hand pump wells, markets, and roads along the railway corridor; and renovated the port in Buchanan, creating facilities to unload and store iron ore from train wagons and transport ore and other materials onto ships (Booth, 2008; Fry, 2014; Kramer, 2011). By 2011, MSL was running 3 trains a day to the port in Buchanan, with 20,000 tons of iron ore transported by each train (Thomashausen & Shah, 2014). The company also built its headquarters in Yekepa, a town located 25 km north of the primary mining site (Mount Tokadeh), and there it invested in housing facilities for its employees, a hospital, a theater, an airstrip, and water, sewerage, and emergency response services (Fry, 2014). Additionally, MSL built a power plant and a power distribution network for the towns of Tokadeh and Yekepa (Booth, 2008), as well as a power plant in Buchanan (ArcelorMittal Liberia, 2012, p. 5). It also rehabilitated a 35 km road from Saniquellie to Yekepa (Booth, 2008), and agreed to pave a 70 km road from Yekepa to Ganta—at a cost of roughly \$40 million (Thomashausen & Shah, 2014).

Estimates vary, but MSL hired somewhere between 2000 and 5000 employees and contractors (Government of Liberia, 2010;

Kramer, 2011; Lanier, Mukpo, & Wilhelmsen, 2012; URS, 2013a). It also provided on-the-job training to local hires (ArcelorMittal Liberia, 2016; Kramer, 2011). As of 2015, MSL claimed that it had achieved “a 96% Liberian employment rate for full-time employees and 99% Liberian rate for contractors” (ArcelorMittal Liberia, 2016, p. 11). These unskilled and semi-skilled jobs pay \$3 or \$3.50 a day, a significant income in a country where “only a small share (less than 10%) of the population earns more than the minimum wage of \$2 per day” (World Bank, 2010, p. 51).

We can also compare pre- and post-treatment outcomes using household surveys undertaken in Yekepa. With respect to *employment*, the percentage of surveyed households with a member employed by MSL increased from 3.3% in 2008 to 10.7% in 2011. Thus, “significant employment opportunities [were] created by the Phase 1 mine operations with residents working either directly for [ArcelorMittal], indirectly with contractors, or with other independent businesses established around the mine community” (URS, 2013a, p. 45). Correspondingly, unemployment declined by 33%.

Households in the nearby towns and villages (including Bonlah, Lugbeyee, Kanlah, Gbapa, Zolowee, and Makinto) saw their *incomes* double, on average (URS, 2013b, p. 41). In the port city of Buchanan, household surveys revealed that individuals in the project-affected areas earned, on average, \$82 more each year than individuals in comparison areas geographically removed from MSL investments. (URS, 2013a, p. 49).²³

Non-concession related business activities also increased. Between 2008 and 2011, the number of households engaged in small business activity increased by 172%. There was also a major increase in “petty trading and service provision,” such as “selling food, artistry, carpentry, hair braiding, [and] motorbike taxi driving.” For example, a camp near the mining site was “built by business entities and private individuals who decided that they could take advantage of the business opportunities provided by the presence of [MSL]” (URS, 2010, p. 31). The mine appears to have prompted a shift away from subsistence farming activities and toward wage labor activities: agricultural work on one’s own farmland declined over the same period of time that private sector employment and small businesses activity spiked (URS, 2013a, p. 46, 88). At the time when post-treatment surveys were conducted, “[t]he number of local businesses is likely to continue to expand as off-shift workers will spend their wages on food, clothing and other products and services” (URS, 2013a, p. 45).

These large-scale changes took relatively little time to materialize. In 2008, the U.S. Embassy reported that “Mittal’s investment is already having a positive impact on the rural population” and it “is already serving as an anchor for other investments in Grand Bassa and Nimba.”²⁴ Several years later, a group of field researchers reported that “Arcelor-Mittal’s presence in the region is ubiquitous, and its impact on the lives of residents in communities near the mine and along the railroad have been immense” (Lanier et al., 2012, p. 20).

6. Conclusion

Governments are typically expected to provide public goods to attract foreign investors, which subsequently results in increased economic activity. But herein lies a catch-22: without economic activity, limited tax revenues are available to finance public goods; and without public goods, limited economic activity generates tax

revenues. To escape this trap, African governments are increasingly requiring that foreign investors provide public goods. We examine if this strategy works.

We present evidence from Liberia suggesting that this type of ‘industrial policy’ can result in economic growth. Concessions that were subject to particularly demanding public good provision requirements (mining investments and iron ore investments) produced higher levels of economic growth than those that faced less demanding public good provision requirements (agricultural and forestry investments). Also, those investors more readily able to satisfy public good requirements (Chinese concessionaires) achieved larger economic growth impacts than investors that were not as well-positioned to meet such requirements (U.S. concessionaires).

While natural resource sector FDI has increased local economic growth in Liberia, it should be noted that foreign investments have not been without challenges. Observers point to political tensions between winners and losers (Paczynska, 2016), the marginalization of indigenous communities in concession negotiations (Qaiyim & Siakor, 2014), and conflicts over land rights (Lanier et al., 2012). There are also reasons to believe that natural resource sector FDI can have negative, second-order effects, such as corruption and environmental degradation (Aragóon & Rud, 2016; Knutsen et al., 2017).

Notwithstanding these caveats, we believe this new form of ‘industrial policy’ merits greater attention. Our study suggests by requiring investors to build and maintain infrastructure near the communities where their commercial activities are sited, governments in resource-rich countries can kick-start local economic agglomeration processes through the development of backward and consumption linkages. In other words, rather than taxing foreign investors and providing public goods themselves, governments can achieve significant economic development gains by using their bargaining power to require the provision of public goods by private actors. This strategy may be particularly attractive to and appropriate for states with limited bureaucratic capacity.

Conflict of interest

None declared.

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²³ The method by which these comparison areas were identified is not made clear in the URS study. Therefore, this evidence should be interpreted as descriptive rather than rigorous counterfactual evidence.

²⁴ “Liberia: ArcelorMittal Initiates Infrastructure Word on Iron Ore Mining Concession.” *U.S. Embassy Cable*, February 8, 2008.

Hewlett Foundation, the College of William and Mary, USAID, or the United States Government. All remaining errors are our own.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at <https://doi.org/10.1016/j.worlddev.2018.02.034>.

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